RIA-80-U741

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MEMORANDUM REPORT ARLCB-MR-80022

DESIGN AND CONSTRUCTION OF A REFINED STEP THREADING MACHINE FOR 175MM AND 8" BREECH RINGS

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June 1980

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
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AMCMS No. 3297.06.6771

PRON No. N1-4-A1632-01-M7-M7

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARLCB-MR-80022	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) DESIGN AND CONSTRUCTION OF A REFINED STEP THREADING MACHINE FOR 175mm AND 8" BREECH RINGS		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) C. H. Rose		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Armament Research and Development Command Benet Weapons Laboratory, DRDAR-LCB-TL Watervliet, N.Y. 12189		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 3297.06.6771 PRON No. N1-4-A1632-01-M7-M7
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research and Development Command Large Caliber Weapon Systems Laboratory Dover, New Jersey 07801		12. REPORT DATE June 1980 13. NUMBER OF PAGES 22
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Originally submitted as an MM&T project to U.S. Army Armament Materiel Readiness Command in April 1980.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Thread Cutting
Step Threads
Thread Shaping
Form Tool Threading

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report details the engineering design and production application of a special purpose machine, tooled to produce internal step threads (constant lead thread on two distinct diameters) on 8" M201 breech rings. The machine, using oscillating motion and a full thread form tool, produces the full thread on each sector, then is indexed in turn to the next sectors until all eight (8) are complete. The use of this equipment has reduced the floor to floor time from 13 hours to 4 hours while producing better thread finishes and more accurate dimensional sizes.

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BENET WEAPONS LABORATORY, LCWSL
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DRDAR-LCB-SE

22 April 1980

Project No: 6746771

Project Title: Design and Construction of a Refined Step Threading Machine for 175mm and 8" Breech Rings

Statement of the Problem: To develop a refined step threading machine which will incorporate the salient features of the original Fairfield step threading machine and include refinements such as required gaging capabilities and safety features to make the equipment amenable to the production threading of 175mm/8" breech rings.

Background and Introduction: The "step-thread" is a thread design in which the mating surfaces of the breechblock and ring are threaded on two diameters generated from the same axial position. The purpose of stepping the thread is to provide the maximum possible surface engagement area with a minimum rotary movement for engagement and disengagement of the block and ring.

The conventional method of machining step-threads in rings is by use of an engine lathe, Figure 1, whose cross slide is automatically traversed "in" and "out" for threading varying diameters or sectors of the rotating workpiece. The lathe's cross slide movement is cam actuated "in" on the cutting stroke and spring actuated on the return or "out" stroke. Failure of spring reaction for any reason will cause the cutting tool to strike the subsequent step, with catastrophic results, usually a broken tool or damaged workpiece. One (1) RPM is the normal machine speed at which the operation is performed (4-5 sfm) on the 175mm and 8 inch ring; at higher RPM, the spring reaction time is not rapid enough to retract the tool for threading the next larger step. The complete threading operation is approximately thirteen (13) hours for a 175mm breech ring.

This project was accomplished as part of the US Army Manufacturing Technology program. The primary objective of this program is to develop, on a timely basis, manufacturing processes, techniques, and equipment for use in production of Army materiel.

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During WWII, an attempt was made by Watervliet Arsenal to speed up production and overcome the bottleneck problem associated with the stepping lathe procedure. The LaSalle Engineering Co. of Chicago was consulted and proposed a broad bladed cutter similar in design to a conventional thread chaser. This cutter would oscillate through the complete width of one sector, completely finishing all the threads on that sector before proceeding to the next sector. The sequence would be repeated until all sectors were completely threaded. A machine was constructed at Watervliet Arsenal and completed in 1943.

Although the fundamental method was sound and the equipment would produce a thread, inherent design defects in the machine prevented the system from ever becoming reliable production equipment. One of the most troublesome aspects was that two different size tools were used for the different diameters of each component, causing thread lead problems. Also, the feed rate was erratic causing an intolerable situation in this operation. At the end of WWII, the machine was eventually discarded as surplus.

During the 25 year span from its conception, this threading innovation was discussed many times regarding its potential if the equipment's defects could be resolved. However, continued anticipation of a "breakthrough" in weapon design whereby step threads would no longer be required, prevented any resolution of the step-thread machining problem until initiation of the current project.

Approach to the Problem: Using FY69 funding, a specification was prepared and a prototype machine purchased to produce step threads in the 175mm and 8" breech ring using a rotary thread shaping method. Using this method, each sector was threaded to desired depth before proceeding to the next sector. Although this machine was capable of only roughing the threads, it resulted in reducing the threading time by four hours.

Based upon the data obtained through the procurement and testing of this machine, it was decided that the machine should be modified to include the necessary functions in order that thread location could be gaged while the component was still located in the machine. In addition, various improvements which were incorporated in a breech block step threading machine (also developed with an MM&T project), were incorporated in the specification for the improved breech ring machine.

Description of the Machine and Breech Ring: Figure 2 shows a 175mm/8" breech ring in which the step thread has already been machined on the Fairfield Step Threading Machine. The ring has a constant lead thread; however, the thread is machined on two different diameters.

When the 175mm/8" ring is threaded in the conventional step threading machine, the tool shown as (Item 1) Figure 3, is used. This tool is form ground to machine one thread tooth and is fed into the component in increments of .001", traversing the full length of the component (14 revolutions) and repeating the sequence until the ring is finished. Approximately thirteen hours are required for floor to floor operation. The threading tool used on the new step threader is a full form tool (Item 2) having all the teeth required to finish one complete sector. The machine oscillates the tool back and forth in an action similar to a washing machine agitator, machining one sector at a time to size. In actual practice, each section is rough machined to within .020" of finished size. During this rough machining, the tool is oscillated at 20 oscillations per minute and the tool is fed in at .0015" per oscillation. After all sectors are rough machined, the cutter is removed and replaced with a newly sharpened tool and the remaining .020" is removed to bring the component to finish size and complete thread form. This threading is also performed at 20 oscillations per minute with the feed reduced to .001" per oscillation for better finish and size control. The threading time is approximately four hours or a nine hour savings over current step threading time.

Figure 4 depicts a front and right side view of the machine. The 30 HP vari-drive spindle drive motor (Item 1) provides a variable oscillation rate from 0 to 25 cycles per minute. The machine base (Item 2) is a fabricated steel weldment, machined to the required tolerances. The crank pin connects the rotary motion being produced by the gear reducer into an oscillating motion required to rotate the spindle.

Figure 5 is a view of the machine table and control station. A 175mm/8" breech ring (Item 1) is shown strapped in position on the machine table by holding clamps (Item 2). The operator's control pendant (Item 3) contains all the necessary electrical control buttons required to operate the machine except for the feed control functions which are located in the main control panel (Item 4).

Figure 6 is a close-up of the top of the cutter head and cutter head support. The cutter head support ring (Item 1) clamps the breech ring to the machine and supports the cutter head (Item 2) through the use of four adjustable bearing shoes (Item 3). The hose connections on the cutter head supply the cutting oil and lubrication oil to the spindle. The hose (Item 4) supplies the cutting oil to the threading

tool while the other hose (Item 5) supplies the spray mist lubricant for the lubrication of the tool block ways in the cutter head. The adjustable stop, (Item 6) provides size control of the cutting tool while the limit switch provides the accurate feed stop required to machine the threads to the accuracy required.

Figure 7 shows the machine table and breech ring raised for the gaging of the step threads for required thread location. The table (Item 1) is raised approximately 15 inches through the use of twin air motors, Figure 8, which activate four ball screws to raise the component. A shoulder location device, Figure 9, is placed inside the breech ring to act as a stop surface for the thread ring gage. The shoulder location device (Item 1) is in the collapsed position for insertion in the breech ring while in (Item 2) the arms are shown extended in the position used while gaging a breech ring. The motion necessary to force the extended arms up against the lower surface of the bushing in the breech ring is supplied by a screw pressure through an adjusting knob (Item 3). In Figure 7 the location device (Item 2) has been inserted in the breech ring (Item 3) and the thread location gage (Item 4) is in position to be lowered in the breech ring for thread location inspection.

Figure 10 is a front view of the operator's console which houses the controls used in machine tool operation. This figure will also be referred to in the section entitled "Step Threading of 175mm/8" Breech Ring". The "Master Start" and "Emergency Stop" buttons are located in the lower left corner of Item 1. The coolant selection button is located in the bottom right hand side and provides for an "Off" position and an "On" position which starts the coolant when tool oscillation is initiated. In the second row of buttons from the bottom are the "Oscillation Start", "Oscillation Jog" and "Oscillation Stop" buttons. The oscillation start button will not operate except when the cutter is in the start position whereas the oscillation jog button can be used to jog the thread cutter through the cycle and return it to the start position for automatic threading.

The thread cutter tool change button controls the location and upward movement of the spindle for tool change operations. The lights show when the cutter head is located in the cutting position "Engaged" or in the cutter change position "Disengaged". The switch between the lights retracts the locking pin "Diseng" and extends the locking pin "Eng" for sector selection. The tool head is moved up and down by the buttons labeled "Tool Head", "Down", "Off", or "Up". With the switch in "Diseng" the tool head can be moved up by placing the "Tool Head" button in the "Up" position. When returning the tool head to the original position, the switch is left in the "Diseng" position and the "Tool Head" button is placed in "Down" position. The tool head will move down until it contacts a safety limit switch. When this happens, the switch is placed in "Eng" position and the "Tool Head Jog Down" button is depressed until

the pin engages and the "Engaged" light comes on. The cutter is then located in the correct position for threading. Caution, the tool head can only be lowered to the correct position when the tool is in the No. 1 thread and in the "Start" position.

The top row of buttons and lights controls the location of the cutter in different step thread positions. The left light indicates when the locating pin is engaged and the red light, second from the right, indicates when the pin is disengaged. Depressing the disengage button withdraws the pin as long as the button is depressed. The positioning switch on the right controls the direction of the index of the tool; CCW = counter clockwise and CW = clockwise rotation of the tool post.

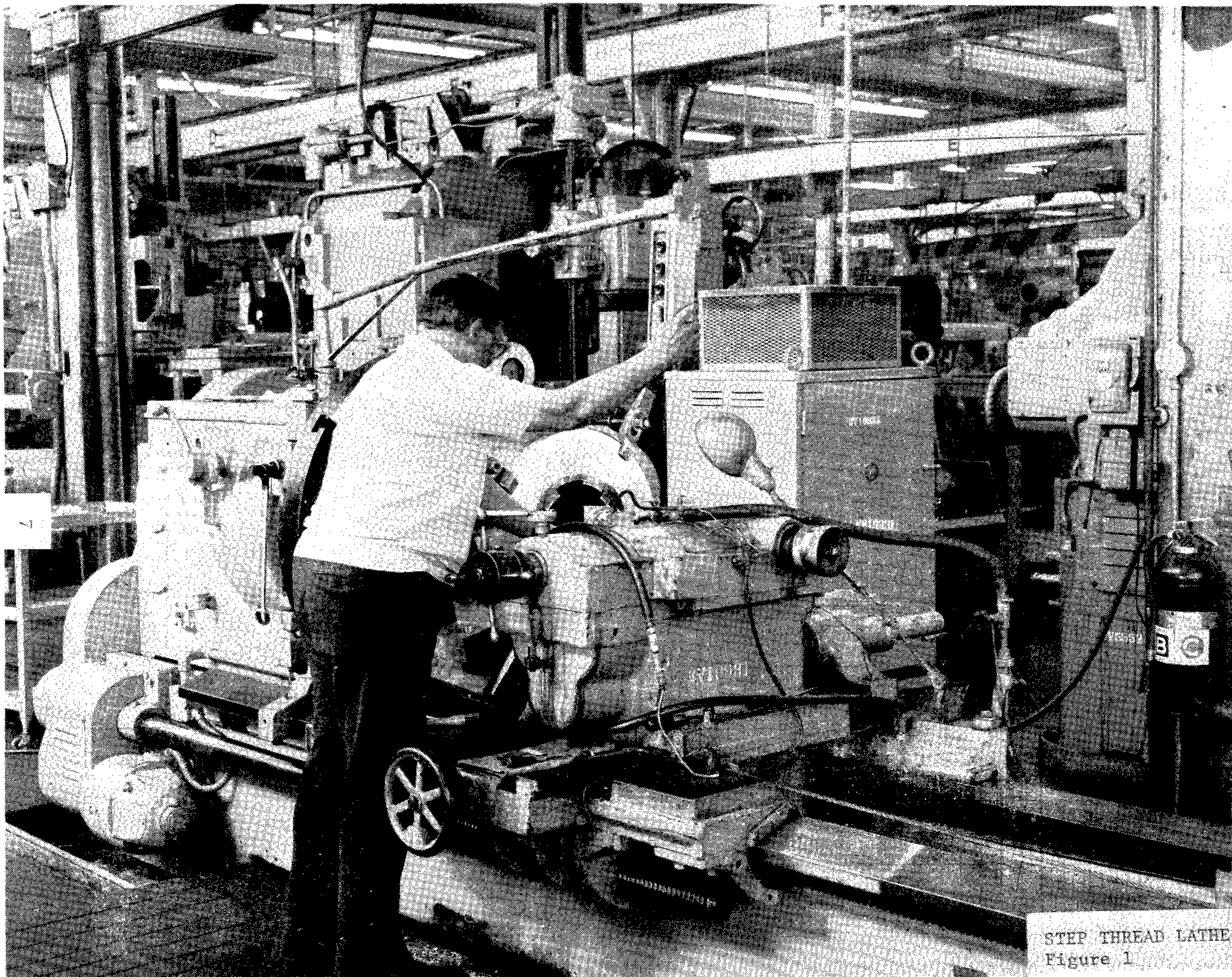
On the left hand panel (Item 2) the rows of lights on the left and right side of the panel designate the position of the tool post in relation to the thread sectors on the breech ring. The green lights (Nos. 1, 3, 5, & 7) are the large step thread diameter and the amber lights (Nos. 2,4,6, and 8) are the small step thread diameters. The top middle button is connected to the safety system and is so designed as to allow an electrical override of the safety system when taking the finished cuts on the step threads (See Appendix A, Procedure for Threading 175mm/8" Breech Rings). The up and down button in the middle section controls the air motors which raise and lower the machine table to provide for the gaging of the step thread. A safety cover was added to the "Down" button to warn the operator not to lower the table without removing the shoulder location device.

Figure 11 shows the stepping motor feed control for controlling the feed of the threading tool. The machine is equipped with a "Slo-syn" preset indexer system (Item 1). The retract portion of the system is preset to retract the tool .010" after each cut. The four numbered control knobs (X1000, X100, X10 and X1) control the infeed of the threading tools. The digital readout (Item 2) indicates the position of the cutting tool and is used to locate the tools at the start of each threading cycle. The ammeter (Item 3) indicates the load on the drive motor during the machining operation. A high ampere reading during the cutting cycle indicates either an excessive depth of cut or a damaged cutting tool.

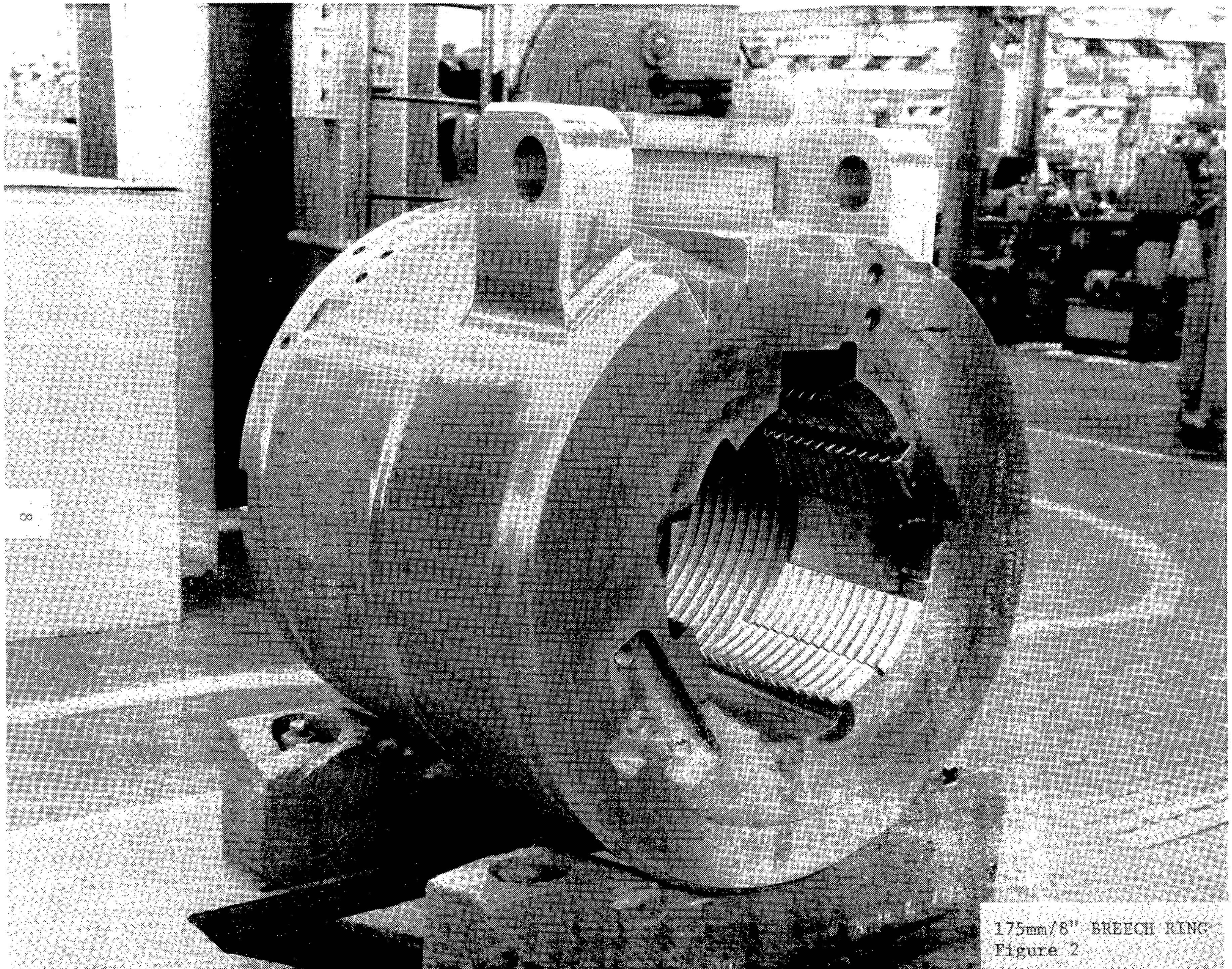
A raised table light (Item 4) was added by Watervliet to protect the machine tool head. The breech ring can be raised for gaging only at one cutting position. Limit switches are set to lock out the raising mechanism except when the tool post is in the correct position at which time the raise table light so indicates.

Figure 12 is a view of the electrical cabinet with the door open. (Item 1)is the chassis containing circuit boards and controls for the Slo-syn feed control unit. The block of switches (Item 2) is the control for the lights and limit switches which control the thread location on the machine and control panels. The remaining switches control and activate the remaining machine functions, i.e., spindle drive motor, coolant pump and air controls.

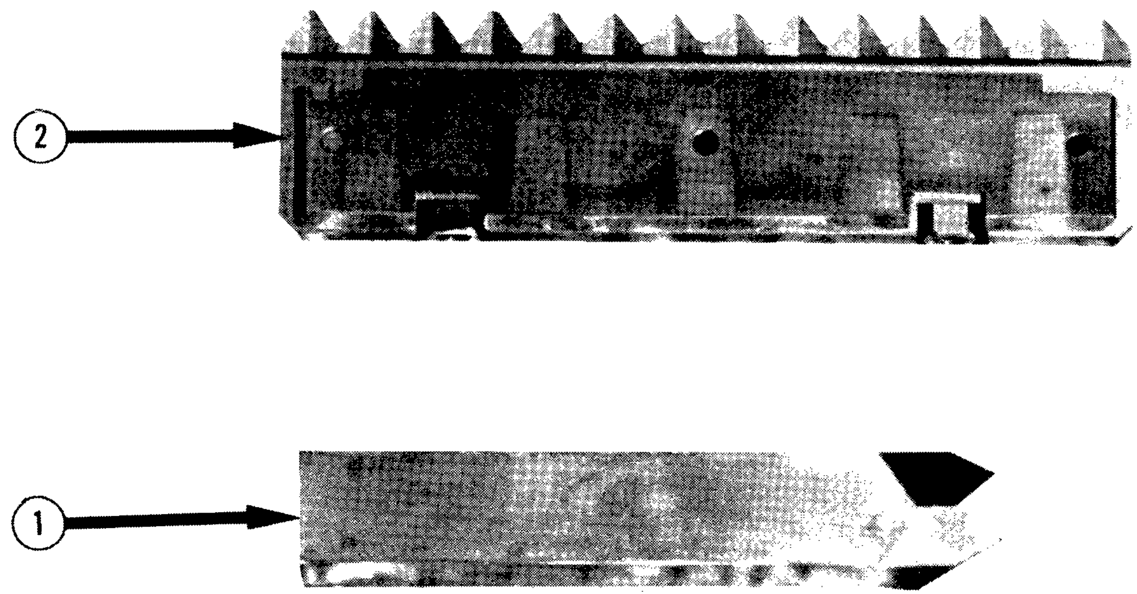
Conclusion and Recommendations: Eight 175mm/8" breech rings have been machined to establish machining parameters and prove the reliability of the thread shaping principle. As a result of this work, it is recommended that all future step threading machines for 175mm/8" breech rings should incorporate the thread shaping principle. Although the initial cost of the blade type tools required for these machines is higher than the cost of conventional step threading tools, the cost of regrind and the expected life of the blade-type tool results in the total cost of the two types of tools being approximately equal. The time required to thread a breech ring conventionally is 13 hours. Through the use of the new step threading equipment the time has been reduced to four hours or a nine hour savings per breech ring threaded. This, translated into dollars, using an estimated $30 per hour including direct labor and overhead, results in a savings of $270 per component threaded. Arsenal Operations has integrated the machine from this project into production.



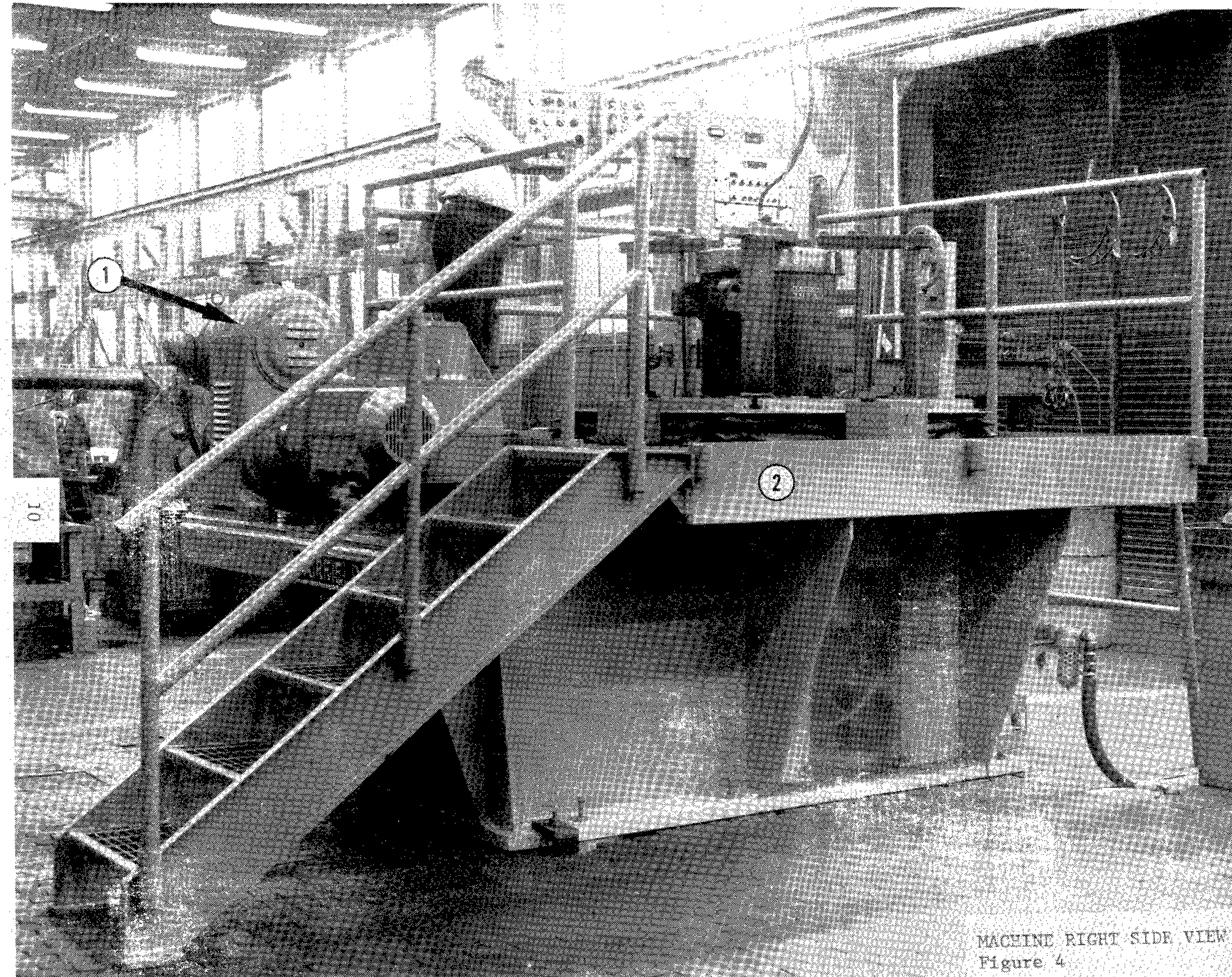
STEP THREAD LATHE
Figure 1



175mm/8" BREECH RING
Figure 2

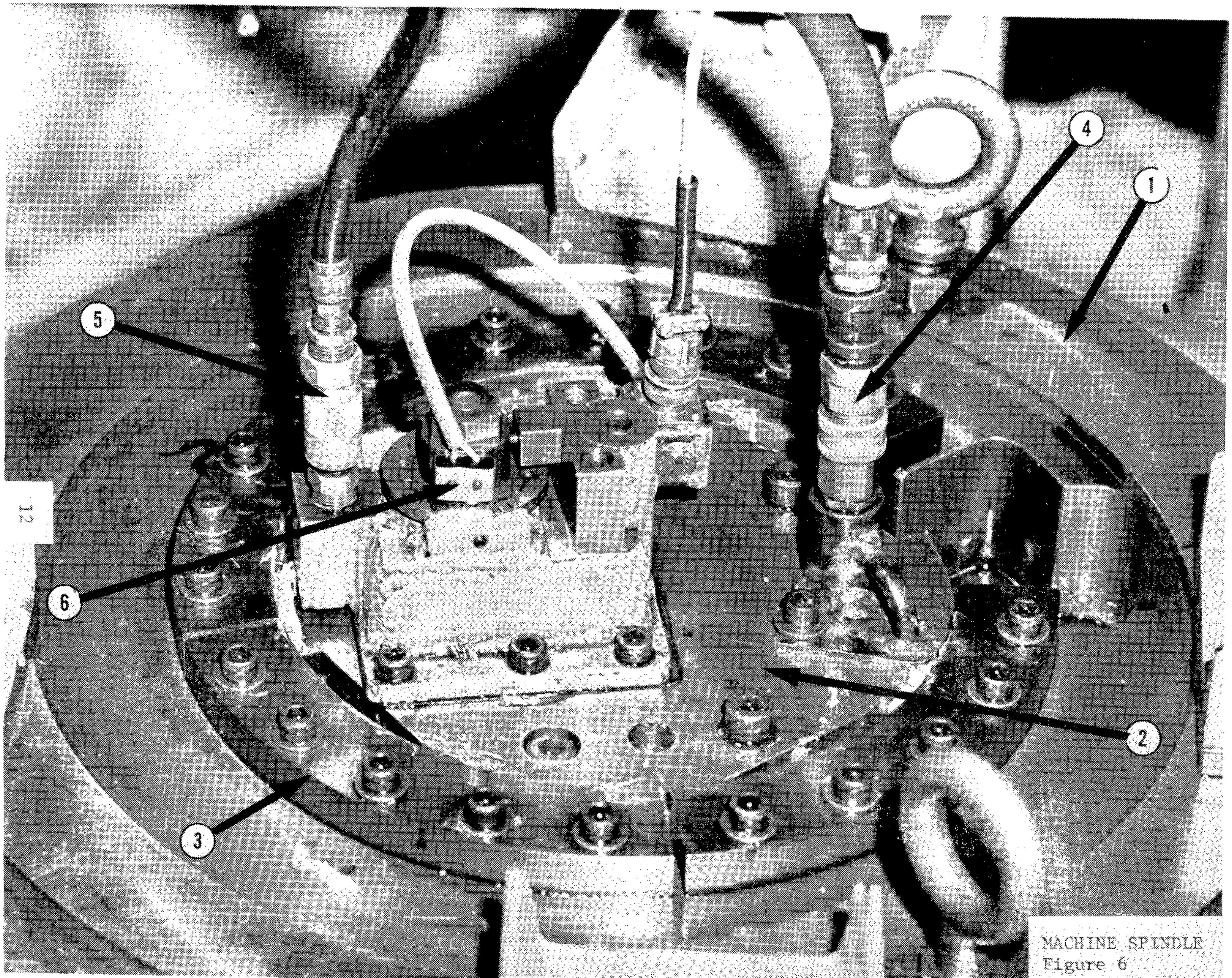


THREADING TOOLS
Figure 3

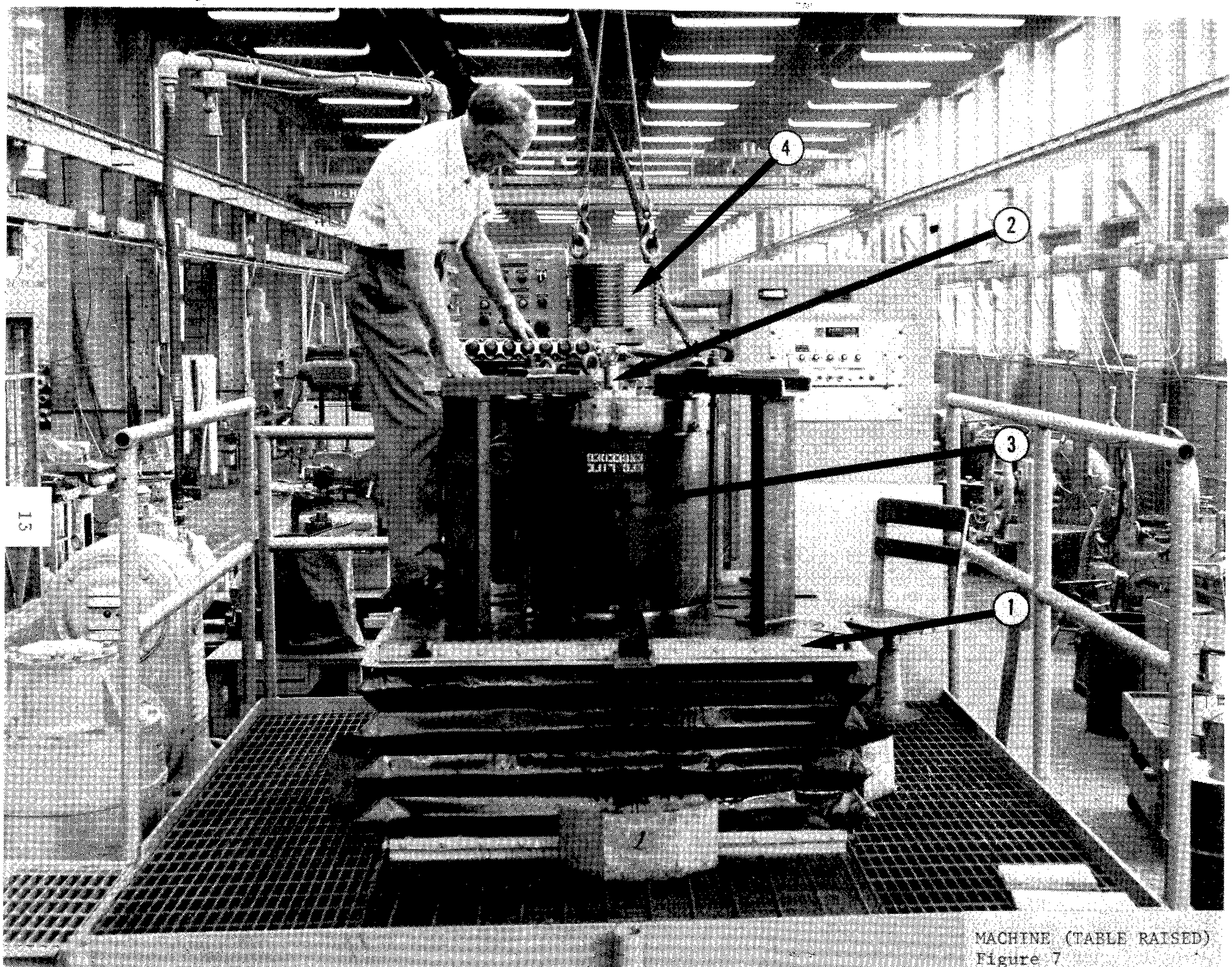


MACHINE RIGHT SIDE VIEW
Figure 4

MACHINE CLOSE-UP
Figure 5



MACHINE SPINDLE
Figure 6



MACHINE (TABLE RAISED)
Figure 7

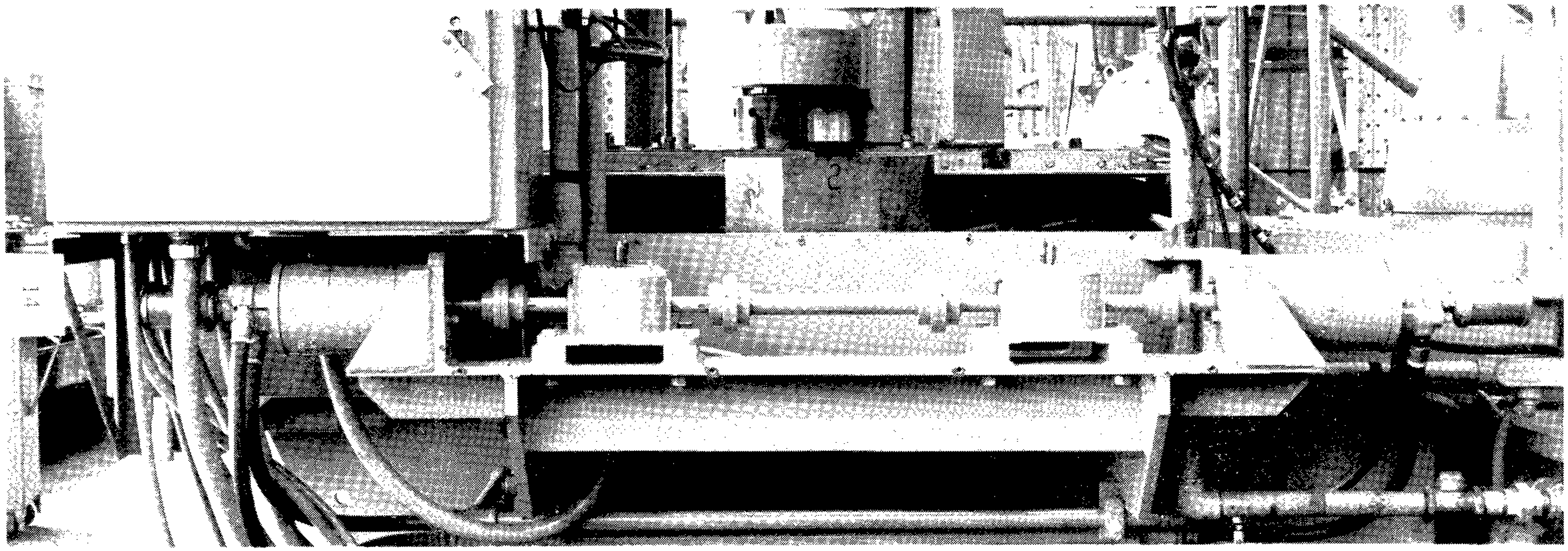
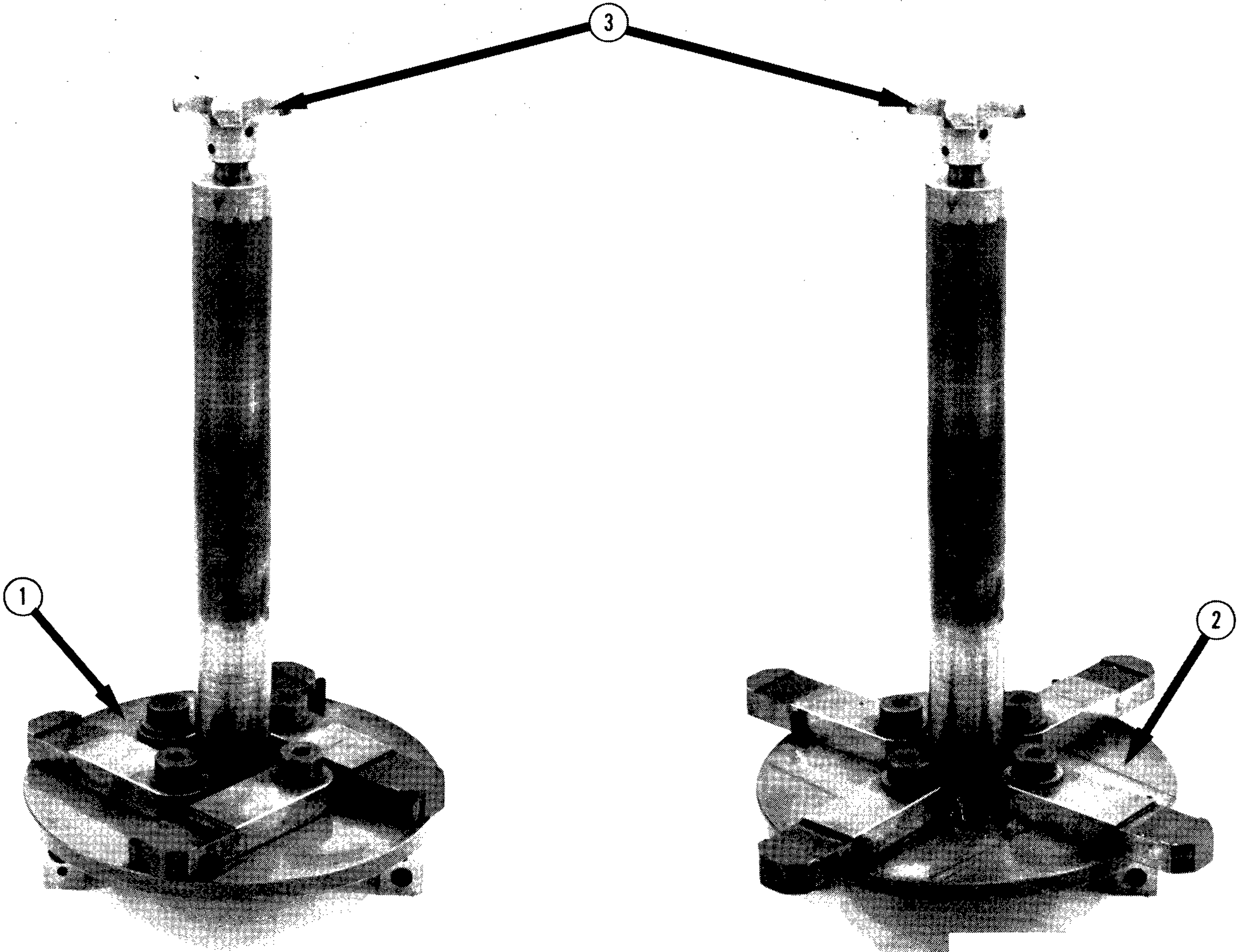
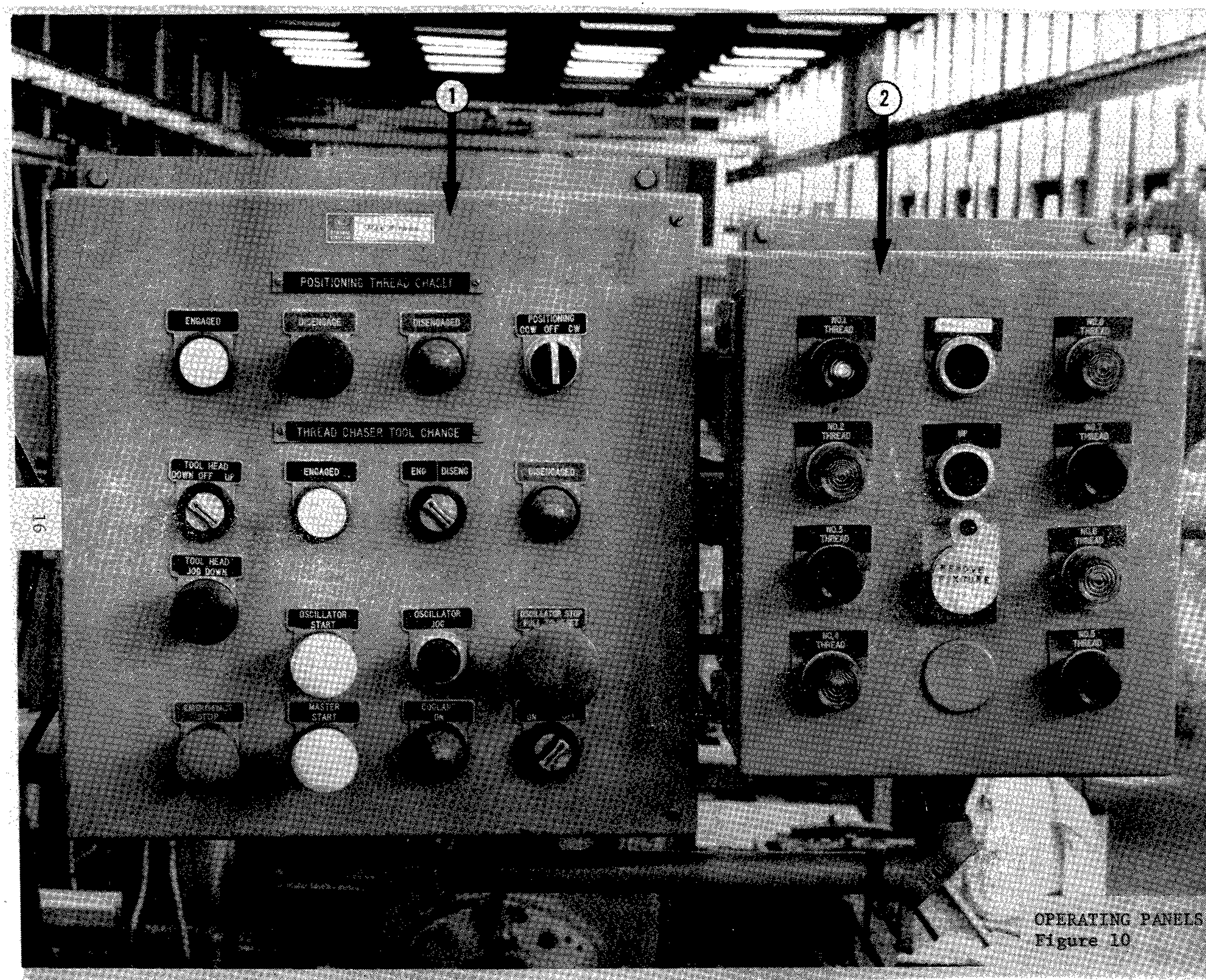


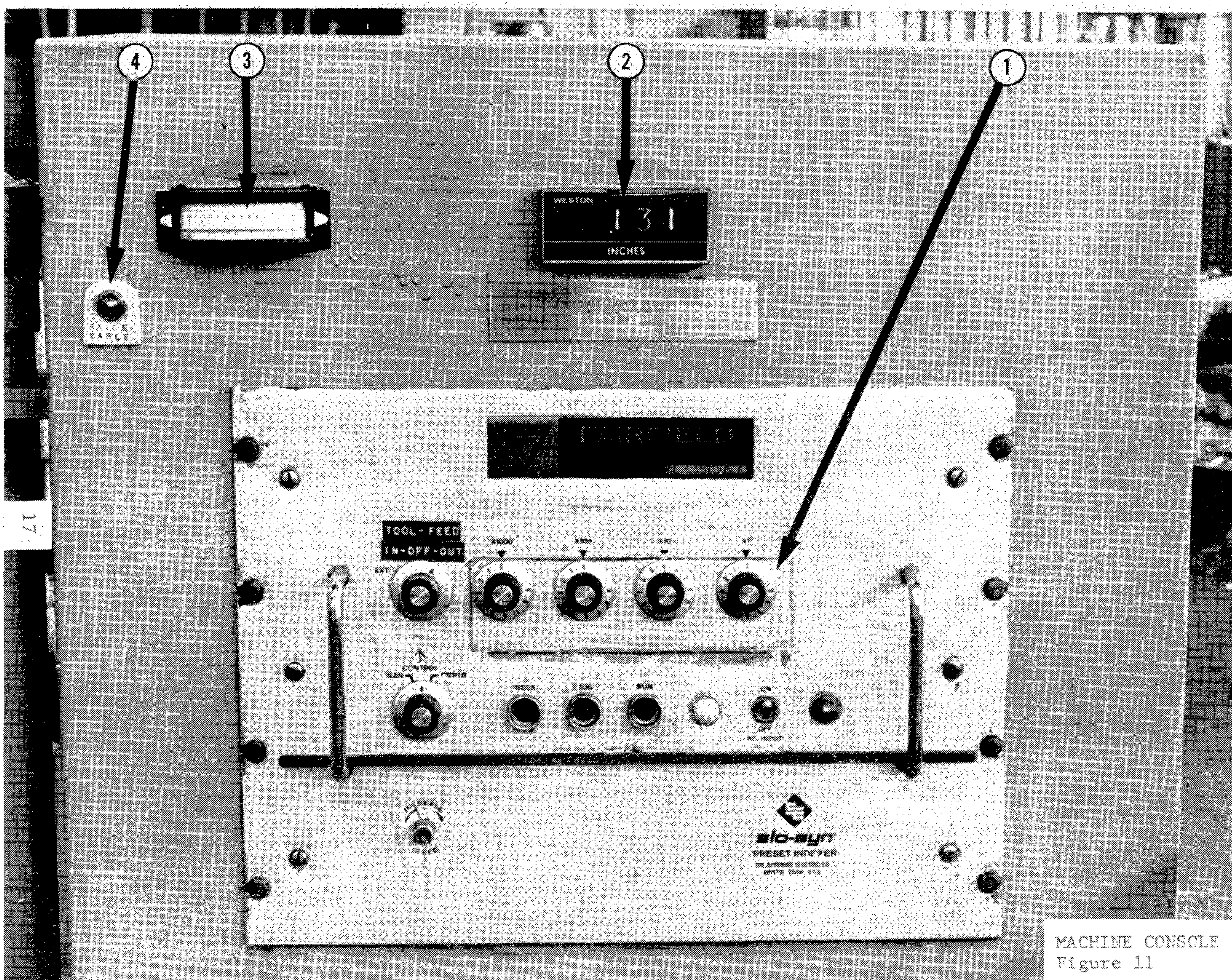
TABLE RAISING SYSTEM
Figure 8



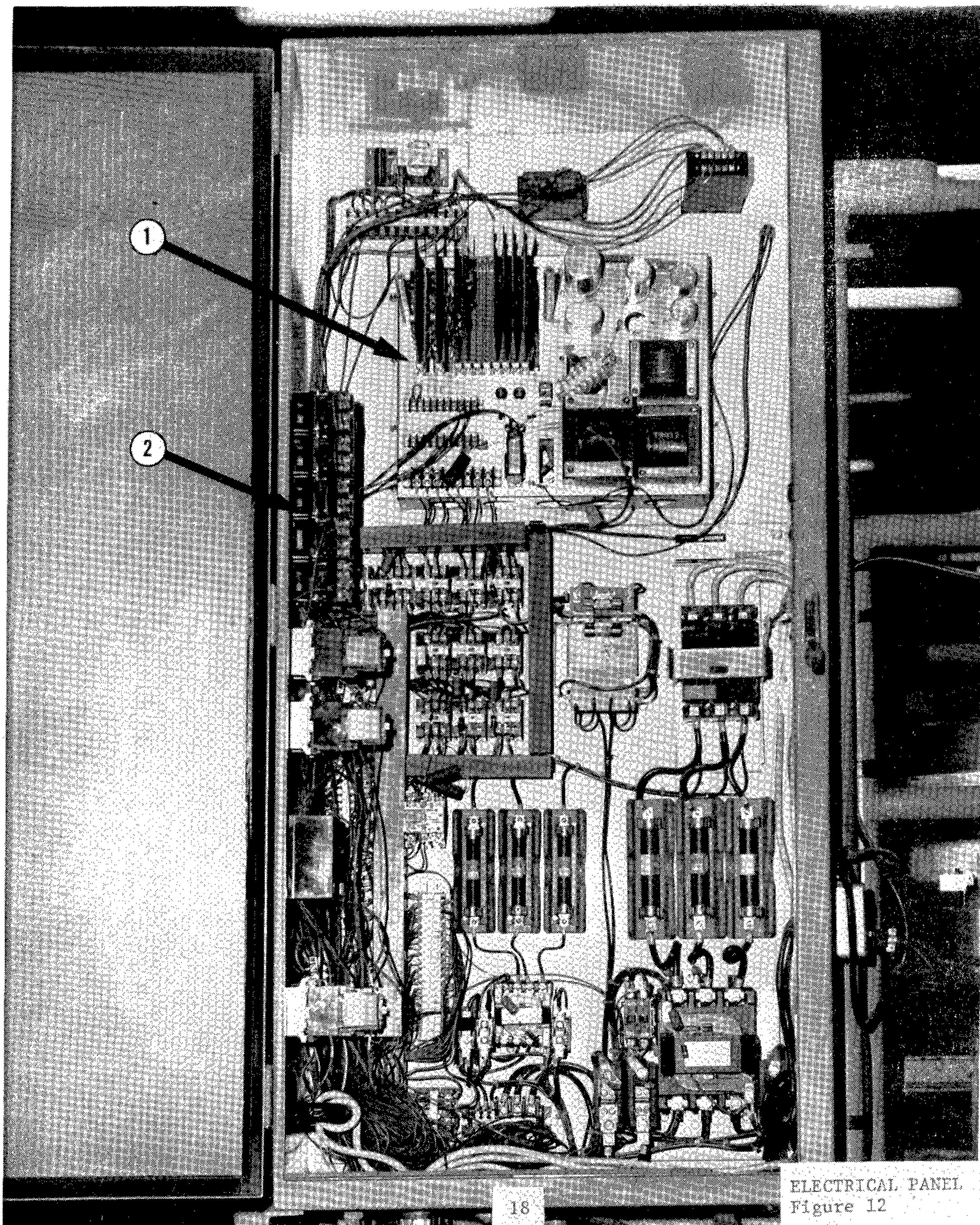
SHOULDER LOCATION DEVICE
Figure 9



OPERATING PANELS
Figure 10



MACHINE CONSOLE
Figure 11



ELECTRICAL PANEL
Figure 12

APPENDIX A

SUBJECT: MMT 6746771 Final Technical Report 22 April 1980

PROCEDURE FOR THREADING 175mm 8" BREECH RINGS
ON THE FAIRFIELD STEP THREAD MACHINE

CUTTING MODE FOR ROUGHING LARGE DIAMETERS

Set tool feed rate on panel at 0-0-4-3 (.0015") for roughing. Turn micrometer depth stop clockwise to limit and return counter clockwise 13 lines. Turn stop rod located by limit switch to L. Adjust oil supply for large sector. Rotate tool to #1 thread.

1. Jog tool to middle of thread sector and advance tool until digital readout reads 1.190. Jog thru cut and return tool to start position. Start oscillation and continue cutting until digital readout reaches 1.650. Fully retract tool, check hook gage location and adjust if necessary.

2. Jog tool to middle of thread sector and advance until digital readout reads 1.640. Jog thru cut and return tool to start position. Start oscillation and continue cutting until feed stops (approx. 1.780 digital readout). Fully retract tool.

3. Index to #3 thread. Jog tool to middle of thread sector and advance tool until digital readout reads 1.190. Jog thru cut and return tool to start position. Start oscillation and continue cutting until feed stops (approx. 1.780 digital readout). Fully retract tool.

4. Repeat paragraph #3 for threads 5 and 7.

CUTTING MODE FOR ROUGHING SMALL DIAMETERS

Leave feed rate and micrometer stop as during previous machining. Turn stop rod located by limit switch to S. Adjust oil supply for small diameter. Rotate to #2 thread.

1. Jog tool to middle of thread sector and advance tool until digital readout reads .190. Jog thru cut and return tool to start position. Start oscillation and continue cutting until feed stops (approx. .721 on digital readout). Fully retract tool.

2. Repeat paragraph 1 for threads 4, 6 and 8.

CUTTING MODE FOR CHANGING TOOL AND CHECKING THREAD LOCATION ON LARGE DIAMETER

Rotate cutter to #1 thread. Jog cutter to best location for tool change. Raise spindle and change cutter. Return spindle to cutting position. Jog tool until Raise Table light is on. Elevate table and blue threads in sections 1, 2 and 6. Lower table to original position (zero on indicator). Set tool feed rate on panel to 0-0-4-0 (.001"). Turn stop located by limit switch to L. Adjust oil supply for large thread sector. Advance micrometer depth stop counter clockwise two lines.

1. Jog tool to middle of thread sector and advance tool until digital readout reads 1.750. Jog thru cut and return to start position. Start oscillation and continue cutting until feed stops (approx. 1.784 digital readout). Fully retract tool. Check with hook gage and adjust tool location if necessary through use of the tool location wheel located on the side of the machine adjacent to the main control panel. Three revolutions of the tool location wheel equal .001" vertical tool movement.

CUTTING MODE FOR FINISHING SMALL DIAMETERS

Turn stop located by limit switch to S. Adjust oil supply for small thread sector. Rotate cutter to No. 2 thread.

1. Jog tool to middle of sector and advance tool until digital readout reads .690. Depress "Finish Cut" button. Jog thru cut and return to start position. Start oscillation and continue cutting until feed stops (approx. .725 digital readout). Fully retract tool.

2. Index to No. 6 thread. Repeat paragraph #1.

3. Rotate table to No. 1 thread and jog until Raise Table light is on. Raise table and measure with ball micrometer across threads 2 and 6. Check for straightness and size. Check ball micrometer reading with outside micrometer. Subtract outside micrometer reading from 10.305 (minimum size for location gage to fit). Turn stop located by limit switch one line for each .002" required on diameter.

4. Repeat paragraph #1 for threads 2, 4, 6 and 8 (approx. .735 on digital readout).

5. Return cutter to #1 thread and jog until Raise Table light is on. Raise table to upmost position. Insert gage locating fixture. Insert location gage and check for correct location. Remove thread location gage and locating fixture. Lower table to original position (0 on indicator). Adjust location if required.

6. After location is established, measure across position 2 and 6 and subtract from finished size of 10.315. Adjust stop limit to obtain required size.

7. Repeat paragraph #1 for threads 2, 4, 6 and 8 starting at .725 on digital readout.

8. Repeat paragraph 5 and check for thread location.

CUTTING MODE FOR FINISHING LARGE DIAMETERS

Turn stop located by limit switch to L. Adjust oil supply for large thread diameter.

1. Jog table to center of sector and advance tool until digital readout reads 1.750. Depress "Finish Cut" button. Jog thru cut and return to start position. Start oscillation and continue cutting until feed stops (approx. 1.800 on digital readout). Fully retract tool.

2. Repeat paragraph 1 for threads 3, 5, and 7.

3. Return cutter to position #1 and jog until Raise Table light is on. Raise table to upmost position. Check for size of large diameter threads using ball micrometer. Diameter over ball should be 11.415, minimum. If diameter is correct, remove clamping ring and check with full form gage for thread concentricity.

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NOTE: PLEASE NOTIFY COMMANDER, ARRADCOM, ATTN: BENET WEAPONS LABORATORY, DRDAR-LCB-TL, WATERVLIET ARSENAL, WATERVLIET, N.Y. 12189, OF ANY REQUIRED CHANGES.